(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 June 2006 (08.06.2006)

PCT

(10) International Publication Number
WO 2006/060002 A1

(51) International Patent Classification:
F02C 3/073 (2006.01) *F01D 5/14* (2006.01)
F04D 25/04 (2006.01) *F01D 5/18* (2006.01)

(21) International Application Number: PCT/US2004/040169

(22) International Filing Date: 1 December 2004 (01.12.2004)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **UNITED TECHNOLOGIES CORPORATION** [US/US]; ONE FINANCIAL PLAZA, HARTFORD, CT 06101 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **NORRIS, James W.** [US/US]; 75 Levita Road, Lebanon, CT 06249 (US). **NORDEEN, Craig A.** [US/US]; 48 Delmont Street, Manchester, CT 06040 (US).

(74) Agent: **WISZ, David L.**; Carlson, Gaskey & Olds, 400 W Maple RD, Suite 350, Birmingham, MI 48009 (US).

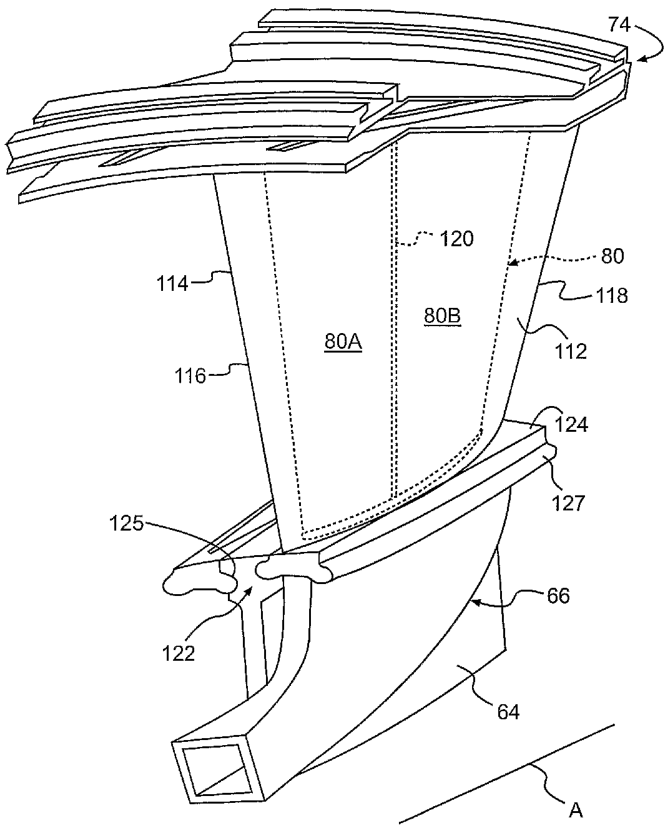
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: FAN BLADE WITH A MULTITUDE OF INTERNAL FLOW CHANNELS



(57) Abstract: A fan-turbine rotor assembly includes a multitude of fan blades, which each includes an inducer section (66), a hollow fan blade airfoil section (73) and a diffuser section (74). A rib (120) located within the airflow passage (80) connects the hollow fan blade airfoil surfaces to increase the structural integrity of the fan blade airfoil section and reduce airflow losses through the core airflow passage due to turbulence.

WO 2006/060002 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

FAN BLADE WITH A MULTITUDE OF FLOW CHANNELS

STATEMENT OF GOVERNMENT RIGHTS

This invention was made with government support under Contract No.: F33657-03-C-2044. The government therefore has certain rights in this invention.

BACKGROUND OF THE INVENTION

The present invention relates to a gas turbine engine, and more particularly to a rib located within a hollow fan blade to increase the structural integrity of the fan blade section and reduce airflow losses when passing air therethrough.

An aircraft gas turbine engine of the conventional turbofan type generally includes a forward fan, a low pressure compressor, a middle core engine, and an aft low pressure turbine all located along a common longitudinal axis. A high pressure compressor and a high pressure turbine of the core engine are interconnected by a high spool shaft. The high pressure compressor is rotatably driven to compress air entering the core engine to a relatively high pressure. This high pressure air is then mixed with fuel in a combustor and ignited to form a high energy gas stream. The gas stream flows axially aft to rotatably drive the high pressure turbine which rotatably drives the high pressure compressor through the high spool shaft. The gas stream leaving the high pressure turbine is expanded through the low pressure turbine which rotatably drives the fan and low pressure compressor through a low pressure shaft.

Although highly efficient, conventional turbofan engines operate in an axial flow relationship. The axial flow relationship results in a relatively complicated elongated engine structure of considerable longitudinal length relative to the engine diameter. This elongated shape may complicate or prevent packaging of the engine into particular applications.

A recent development in gas turbine engines is the tip turbine engine. Tip turbine engines locate an axial compressor forward of a bypass fan which includes hollow fan blades that receive airflow from the axial compressor therethrough such that the hollow fan blades operate as a centrifugal compressor. Compressed core airflow from the hollow fan blades is mixed with fuel in an annular combustor and ignited to form a high energy gas stream which drives the turbine integrated onto the tips of the hollow bypass fan blades for rotation therewith as generally disclosed in U.S. Patent Application Publication Nos.: **20030192303**; **20030192304**; and **20040025490**.

The tip turbine engine provides a thrust to weight ratio equivalent to conventional turbofan engines of the same class within a package of significantly shorter length.

The tip turbine engine utilizes hollow fan blades as a centrifugal impeller. Axial airflow from an upstream source such as ambient or an axial compressor must be turned into a radial airflow for introduction into the hollow fan blades. Communicating airflow through the hollow fan blades within a relatively compact space of a fan turbine rotor provides an engine design challenge.

Accordingly, it is desirable to provide a lightweight hollow fan blade with a core airflow passage while minimizing the reduction in structural integrity of the fan blade.

SUMMARY OF THE INVENTION

The fan-turbine rotor assembly for a tip turbine engine according to the present invention includes a multitude of fan blades which include an inducer section, a hollow fan blade section and a diffuser section. The hollow fan blade section defines a core airflow passage between a first surface mounted to a second surface at a leading edge and a trailing edge. The surfaces form the fan blade airfoil.

A rib located within the core airflow passage connects the surfaces to increase the structural integrity of the fan blade section and reduce airflow losses through the core airflow passage due to turbulence.

The present invention therefore provides a lightweight hollow fan blade with a core airflow passage while minimizing the reduction in structural integrity of the fan blade.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the currently preferred embodiment. The drawings that accompany the detailed description can be briefly described as follows:

Figure 1 is a partial sectional perspective view of a tip turbine engine;

Figure 2 is a longitudinal sectional view of a tip turbine engine along an engine centerline;

Figure 3 is a partial phantom view of a fan blade illustrating the airflow passage therein; and

Figure 4 is a partial sectional view of another fan blade illustrating the airflow passage therein.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 illustrates a general perspective partial sectional view of a tip turbine engine type gas turbine engine 10. The engine 10 includes an outer nacelle 12, a rotationally fixed static outer support structure 14 and a rotationally fixed static inner support structure 16. A multitude of fan inlet guide vanes 18 are mounted between the static outer support structure 14 and the static inner support structure 16. Each inlet guide vane 18 preferably includes a variable trailing edge 18A variable relative to the fixed inlet guide vane 18.

A nose cone 20 is preferably located along the engine centerline A to smoothly direct airflow into an axial compressor 22 adjacent thereto. The axial compressor 22 is mounted about the engine centerline A behind the nose cone 20.

A fan-turbine rotor assembly 24 is mounted for rotation about the engine centerline A aft of the axial compressor 22. The fan-turbine rotor assembly 24 includes a multitude of hollow fan blades 28 to provide internal, centrifugal compression of the compressed airflow from the axial compressor 22 for distribution to an annular combustor 30 located within the rotationally fixed static outer support structure 14. Although two turbine stages are disclosed in the illustrated embodiment, it should be understood that any number of stages may be utilized by the instant invention.

A turbine 32 includes a multitude of tip turbine blades 34 (two stages shown) which rotatably drive the hollow fan blades 28 relative a multitude of tip turbine stators 36 which extend radially inwardly from the static outer support structure 14. The annular combustor 30 is axially forward of the turbine 32 and communicates with the turbine 32.

Referring to Figure 2, the rotationally fixed static inner support structure 16 includes a splitter 40, a static inner support housing 42 and an static outer support housing 44 located coaxial to said engine centerline A. An aft housing 45 is attached to the static inner support housing 42 and the static outer support housing 44 through fasteners f such as bolts or the like. The static inner support housing 42, the static outer support housing 44, and the aft housing 45 are located about the engine centerline A to provide the non-rotating support structure for the engine 10.

The axial compressor 22 includes the axial compressor rotor 46 from which a plurality of compressor blades 52 extend radially outwardly and a compressor case 50 fixedly mounted to the splitter 40. A plurality of compressor vanes 54 extend radially inwardly from the compressor case 50 between stages of the compressor blades 52. The compressor blades 52 and compressor vanes 54 are arranged circumferentially about the axial compressor rotor 46 in stages (three stages of compressor blades 52 and compressor vanes 54 are shown in this example). The axial compressor rotor 46 is mounted for rotation upon the static inner support housing 42 through a forward bearing assembly 68 and an aft bearing assembly 62.

The fan-turbine rotor assembly 24 includes a fan hub 64 that supports a multiple of the hollow fan blades 28. Each fan blade 28 includes, beginning from a radially inner location to a radially outer location, an inducer section 66, a hollow airfoil section 72 and a diffuser section 74. The inducer section 66 receives airflow from the axial compressor 22 generally parallel to the engine centerline A and turns the airflow from an axial airflow direction toward a radial airflow direction. The airflow is radially communicated through a core airflow passage 80 defined through the hollow airfoil section 72 where the airflow is centrifugally compressed. From the core airflow passage 80, the airflow is turned and diffused toward an axial airflow direction toward the annular combustor 30. Preferably the airflow is diffused axially forward in the engine 10, however, the airflow may alternatively be communicated in another direction.

A gearbox assembly 90 aft of the fan-turbine rotor assembly 24 provides a speed increase between the fan-turbine rotor assembly 24 and the axial compressor 22. Alternatively, the gearbox assembly 90 could provide a speed decrease between the fan-turbine rotor assembly 24 and the axial compressor rotor 46. The gearbox assembly 90 is mounted for rotation between the static inner support housing 42 and the static outer support housing 44. The gearbox assembly 90 includes a sun gear shaft 92 which rotates with the axial compressor 22 and a planet carrier 94 which rotates with the fan-turbine rotor assembly 24 to provide a speed differential therebetween. The gearbox assembly 90 is preferably a planetary gearbox that provides co-rotating or counter-rotating rotational engagement between the fan-turbine rotor assembly 24 and an axial compressor rotor 46. The gearbox assembly 90 is mounted for rotation between the sun gear shaft 92 and the static outer support housing 44 through a forward bearing 96 and a rear bearing 98. The forward bearing 96 and the rear bearing 98 are both tapered roller bearings and both handle radial loads. The forward bearing 96 handles the aft axial loads while the rear bearing 98 handles the forward axial loads. The sun gear shaft 92 is rotationally engaged with the axial compressor rotor 46 at a splined interconnection 100 or the like.

In operation, air enters the axial compressor 22, where it is compressed by the three stages of the compressor blades 52 and compressor vanes 54. The compressed air from the axial compressor 22 enters the inducer section 66 in a direction generally parallel to the engine centerline A and is turned by the inducer section 66 radially outwardly through the core airflow passage 80 of the hollow fan blades 28. The airflow is further compressed centrifugally in the hollow fan blades 28 by rotation of the hollow fan blades 28. From the core airflow passage 80, the airflow is turned and diffused axially forward in the engine 10 into the annular combustor 30. The compressed core airflow from the hollow fan blades 28 is mixed with fuel in the annular combustor 30 and ignited to form a high-energy gas stream. The high-energy gas stream is expanded over the multitude of tip turbine blades 34 mounted about the outer periphery of the fan blades 28 to drive the fan-turbine rotor assembly 24, which in turn drives the axial compressor 22 through the gearbox assembly 90. Concurrent therewith, the fan-turbine rotor assembly 24 discharges fan bypass air axially aft to merge with the core airflow from the turbine 32 in an exhaust case 106. A multitude of exit guide vanes 108 are located between the static outer support housing 44 and the nonrotatable static outer support structure 14 to guide the combined airflow out of the engine 10 to provide forward thrust. An exhaust mixer 110 mixes the airflow from the turbine blades 34 with the bypass airflow through the fan blades 28.

Referring to Figure 3, the fan blade 28 includes the inducer section 66, the hollow airfoil section 72 and the diffuser section 74. The hollow airfoil section 72 defines the core airflow passage 80 and includes a first airfoil surface 112 and a second airfoil surface 114 merging at a leading edge 116 and a trailing edge 118. The airfoil surfaces 112, 114 form the fan blade airfoil shape.

The fan hub 64 retains each hollow airfoil section 72 through a blade receipt section 122 such as a scalloped outer hub periphery. Each blade receipt section 122 preferably forms an axial semi-cylindrical opening 125 formed along the axial length of the fan hub 64. Each hollow airfoil section 72 includes a fan blade mount section 124 that corresponds with the blade receipt section 122 to retain the hollow airfoil section 72 within the fan hub 64. The fan blade mount 124 preferably includes a semi-cylindrical portion 127 to radially retain the fan blade 28. It should be understood that other retention structures such as a dove-tail, fir-tree, or bulb-type engagement structure will likewise be usable with the present invention.

A rib 120 is located within the core airflow passage 80. The rib 120 is arranged along a radial flow path of the core airflow passage 80. The core airflow passage 80 is thereby separated into a first core airflow passage 80a and a second core airflow passage 80b by the rib 120. The rib 120 preferably bridges the airfoil surfaces 112, 114 to increase the structural integrity of the fan blade airfoil section 72, however, the rib 120 may alternatively extend from either of the surfaces 112, 114 and be spaced away from the other of the surfaces 114, 112.

The ribs 120 are preferably constructed to guide the flow in the core airflow passage 80. Without the ribs, airflow may be slung (compressed) against the rear of the core airflow passage 80. This may lead to flow turbulence, and inefficiency. By locating the ribs within the core airflow passage 80, the airflow is divided into the several core airflow passages 80a, 80b which provides a more even airflow distribution, with a smoother transition into the diffuser section. It should be understood that any number of passages and ribs may be used with the present invention.

The inducer section 66 turns the airflow radially outward toward the core airflow passage 80 within each fan blade airfoil section 72. The rib 120 provides increased control to minimize flow separation once the airflow is turned by the inducer section 66 to reduce airflow losses due to turbulence.

Referring to Figure 4, a multiple of additional ribs 128 may additionally be located within the core airflow passage 80a, 80b to further guide the airflow. The ribs 128 may be alternatively segmented, non-linear, or additionally may not extend for the full radial length of the core airflow passage 80 and/or may be contoured to control flow turbulence from the inducer section 66. Notably, the fan-turbine rotor 24' of Figure 4 is a one-piece fan hub 64', which will also benefit from the instant invention.

It should be understood that the ribs 120 located within the core airflow passage 80 of the fan blades 28 may be formed by casting, fabrication (diffusion bonding, welding, etc) or by some direct form method like laser deposition. The concept is applicable to a fan blade 28 in any form it might take.

It should be understood that relative positional terms such as "forward," "aft," "upper," "lower," "above," "below," and the like are with reference to the normal operational attitude of the vehicle and should not be considered otherwise limiting.

The foregoing description is exemplary rather than defined by the limitations within. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. For that reason the following claims should be studied to determine the true scope and content of this invention.

CLAIMS

What is claimed is:

1. A fan blade assembly comprising:
a fan blade section which defines an airflow passage therethrough; and
at least one rib located within said airflow passage.

2. The fan blade assembly as recited in claim 1, wherein said rib extends for the length of said airflow passage.

3. The fan blade assembly as recited in claim 1, wherein said rib includes a multitude of ribs.

4. The fan blade assembly as recited in claim 1, wherein said fan blade section includes a first airfoil surface and a second airfoil surface merging at a leading edge and a trailing edge to form an airfoil shape, which defines said airflow passage, said rib mounted between said first airfoil surface and said second airfoil surface.

5. The fan blade assembly as recited in claim 1, wherein said rib is mounted to said first airfoil surface and spaced from said second airfoil surface.

6. The fan blade assembly as recited in claim 1, wherein said rib is segmented.

7. The fan blade assembly as recited in claim 6, wherein said segmented rib is non-linear.

8. The fan blade assembly as recited in claim 7, further comprising a solid rib adjacent said segmented rib.

9. The fan blade assembly as recited in claim 8, wherein said segmented rib extends for a length less than a length of said solid rib.

10. A method of communicating a core airflow through a fan blade comprising the steps of:

(1) directing an airflow through a airflow passage within a fan blade section; and

(2) dividing the airflow into a multitude of airflows within the fan blade section.

11. A method as recited in claim 10, wherein said step (2) further comprises:

reducing a turbulence of the airflow within the fan blade.

12. A method as recited in claim 10, wherein said step (2) further comprises:

reducing a flow separation of the airflow within the fan blade.

13. A method as recited in claim 10, further comprises the step of:

directing the multitude of airflows toward a diffuser section in fluid communication with an annular combustor mounted adjacent a tip of fan blade.

14. A fan blade, comprising:

an airfoil section;

an airflow passage through said airfoil section;

an entrance in communication with said internal passage;

an exit in communication with said internal passage; and

at least one rib within said airflow passage.

15. The fan blade as recited in claim 14, wherein said rib extends for the length of said airflow passage.

16. The fan blade as recited in claim 14, wherein said rib includes a multitude of ribs.

17. The fan blade as recited in claim 14, wherein said fan blade section includes a first airfoil surface mounted to a second airfoil surface at a leading edge and a trailing edge to form an airfoil shape, which defines said airflow passage, said rib mounted between said first airfoil surface and said second airfoil surface.

18. The fan blade as recited in claim 14, wherein said rib is mounted to said first airfoil surface and spaced from said second airfoil surface.

19. The fan blade as recited in claim 14, wherein said airflow passage through said airfoil section is a core airflow passage.

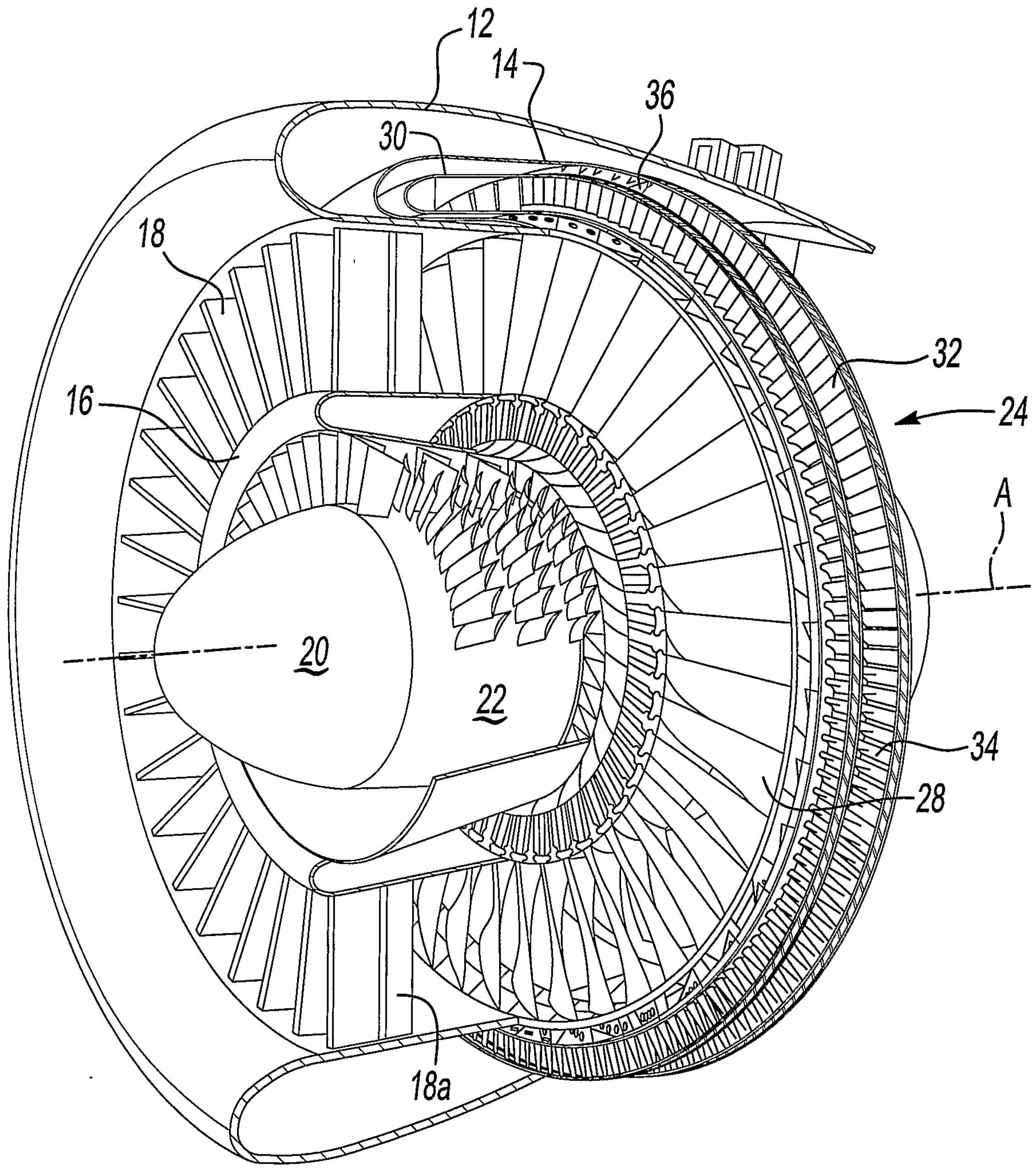


Fig-1

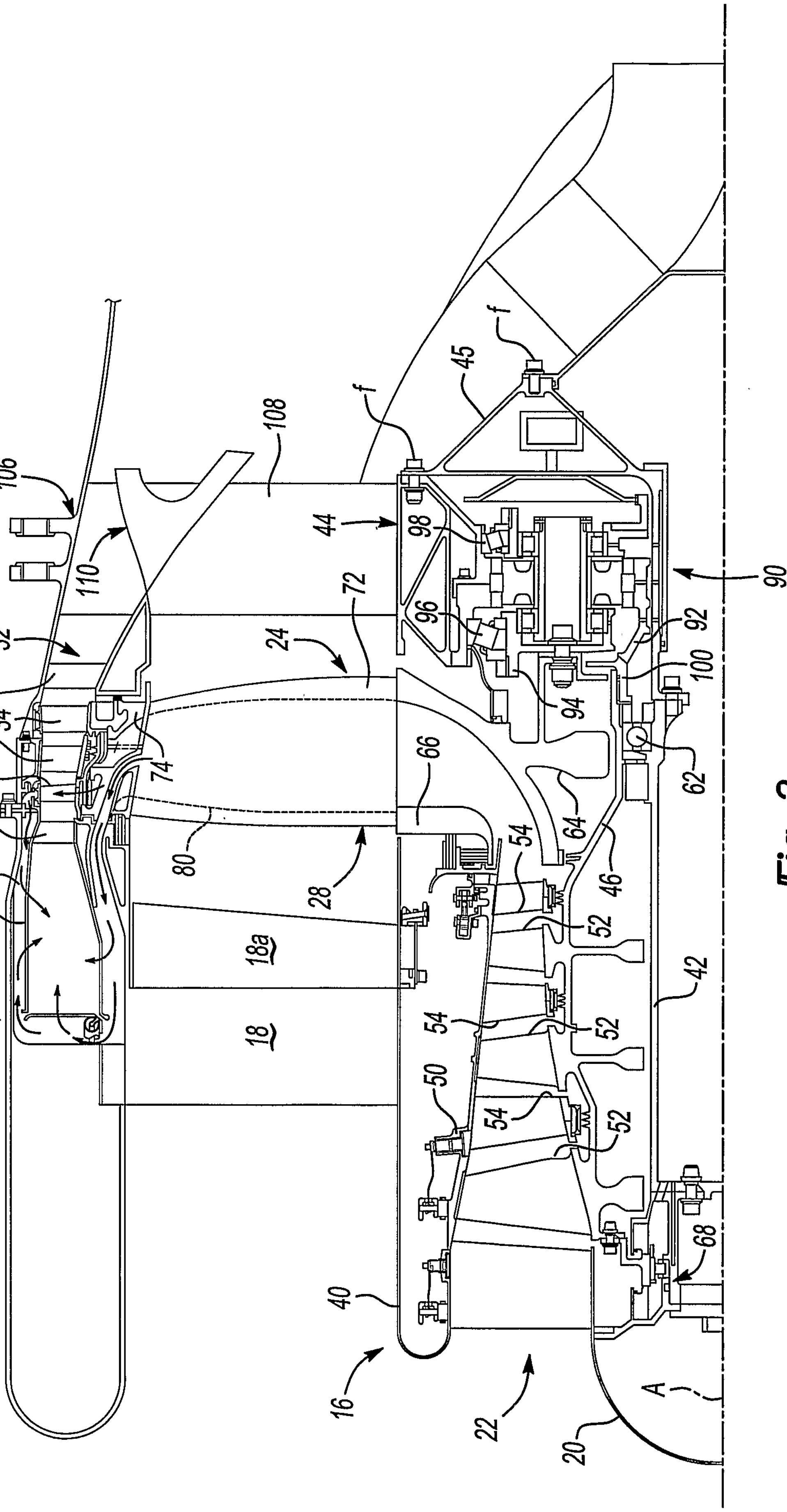

12
14
16
18
18a
20
22
24
28
30
32
34
36
40
42
44
45
46
50
52
54
62
64
66
68
72
74
80
90
92
94
96
98
100
106
108
110
f
A

Fig-2

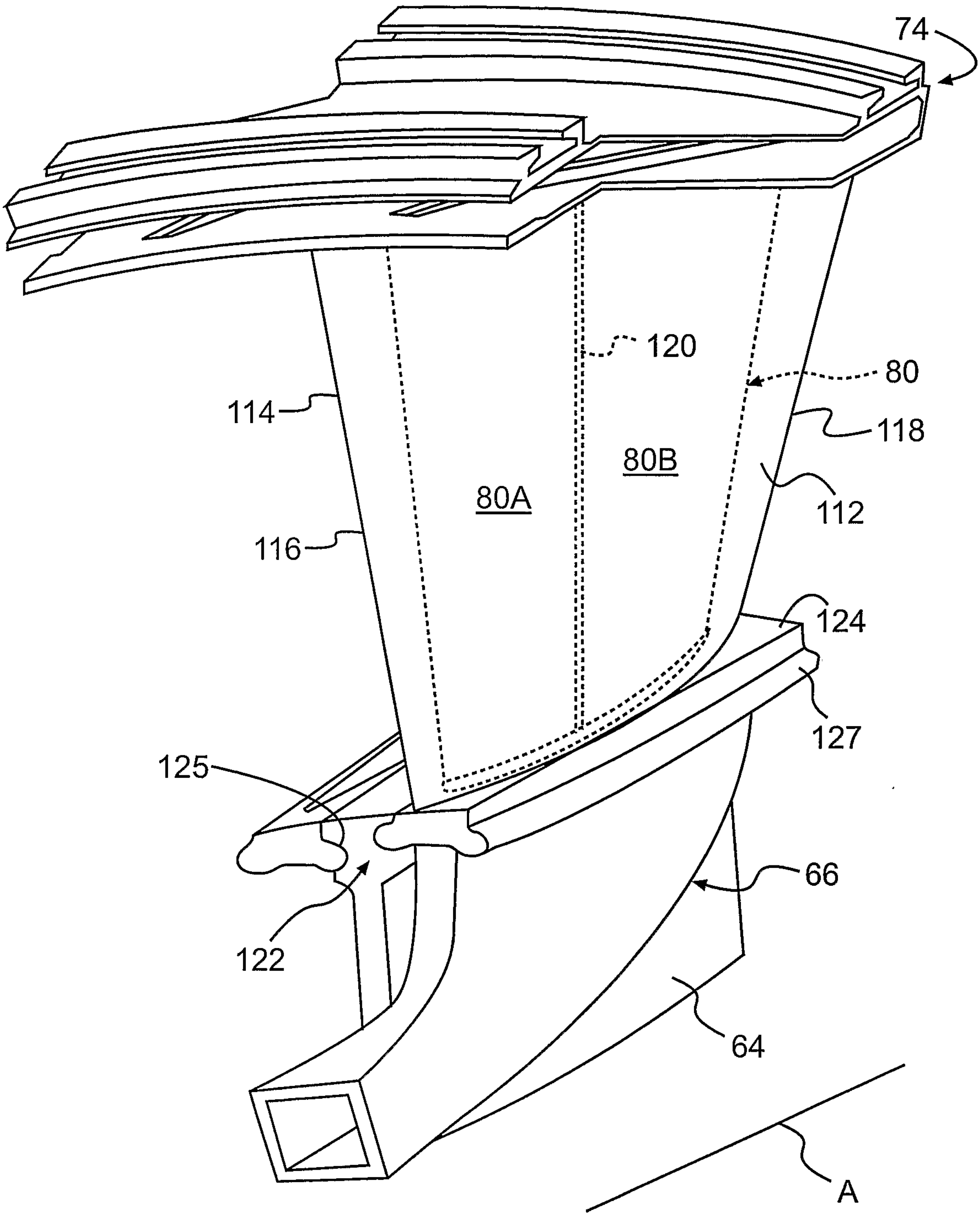


FIG. 3

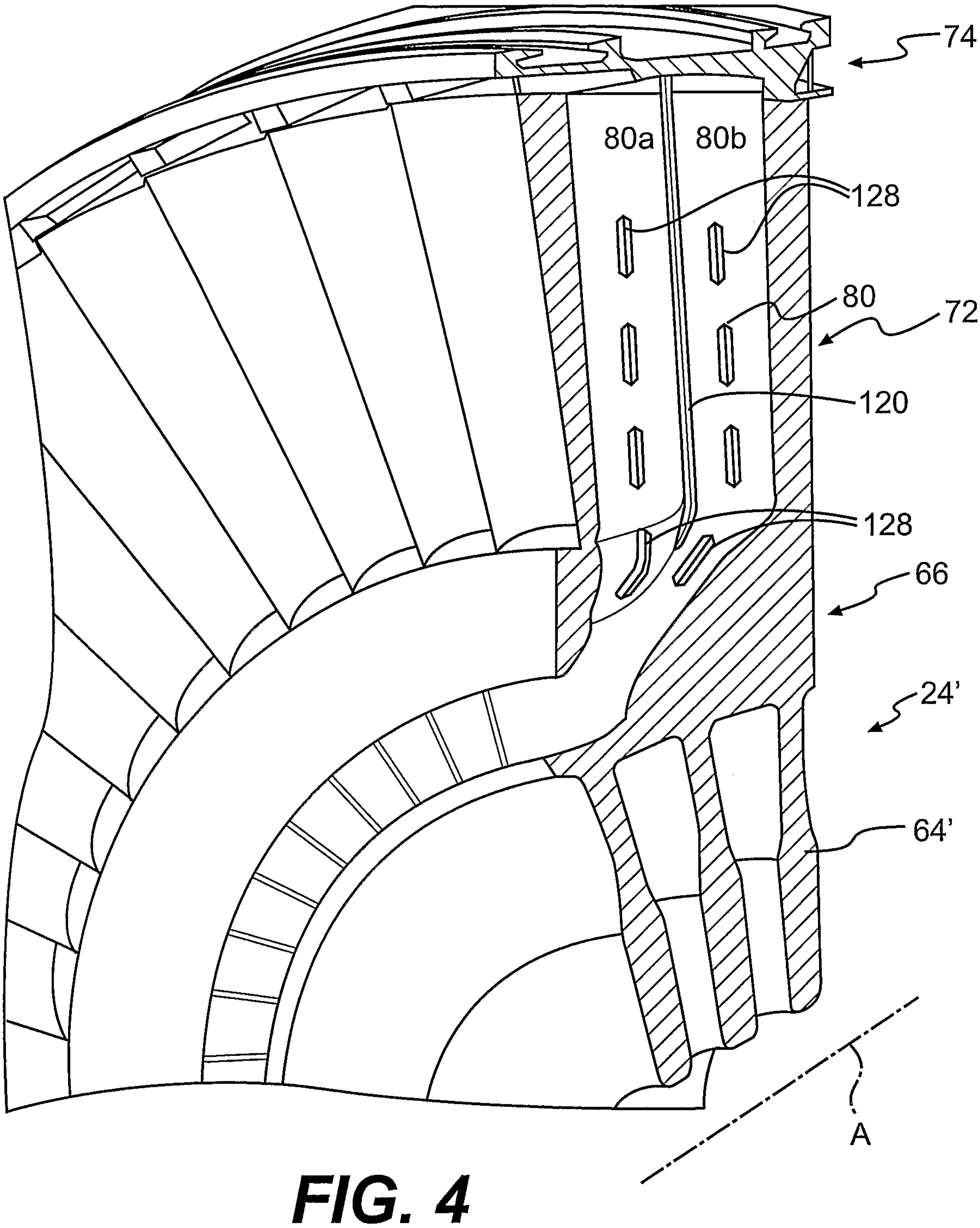


FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
. ˘T/US2004/040169

A. CLASSIFICATION OF SUBJECT MATTER
F02C3/073 F04D25/04 F01D5/14 F01D5/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02C F04D F01D F02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 766 728 A (GARRETT CORPORATION) 23 January 1957 (1957-01-23) page 2, line 111 - page 3, line 9 page 3, line 65 - page 4, line 20; figures	1-3, 10-12, 14-16,19
X	DE 765 809 C (MARTINKA MICHAEL DIPL.-ING; DR.-ING. PAUL H. MUELLER) 29 November 1954 (1954-11-29) page 2, line 83 - line 93; figures	1,10,14
Y	US 3 283 509 A (NITSCH HARRI) 8 November 1966 (1966-11-08) column 2, line 23 - line 42; figure 1	1-4, 10-17,19

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 December 2005	18/01/2006

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	de Rooij, M

INTERNATIONAL SEARCH REPORT

International Application No
, ᴗT/US2004/040169

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 02/081883 A (SEEFLUTH, UWE, CHRISTIAN) 17 October 2002 (2002-10-17) page 1, last paragraph - page 2, paragraph 3 page 9, paragraph 3 - paragraph 5; figure 2 page 14, paragraph 7 - paragraph 8; figure 14 page 15, paragraph 2; figure 17 page 15, last paragraph - page 16, paragraph F; figures 22a,22b page 16, paragraph 8; figure 23g	1-4, 10-17,19
X	US 2 611 241 A (SCHULZ THEODORE R) 23 September 1952 (1952-09-23) column 1, line 5 - line 34 column 3, line 22 - column 4, line 28; figure 1	10-13
X	US 2004/025490 A1 (PAUL MARIUS A) 12 February 2004 (2004-02-12) cited in the application	10
Y	paragraphs ‘0012!, ‘0013!, ‘0065! - ‘0073!, ‘0084!, ‘0097! - ‘0107!, ‘0139!; figures 1,9,11,12,21,29	1-4, 14-17,19
Y	US 5 584 660 A (CARTER ET AL) 17 December 1996 (1996-12-17) column 1, line 21 - line 60; figures	1-4, 14-17,19
A	US 4 631 092 A (RUCKLE ET AL) 23 December 1986 (1986-12-23) the whole document	1-4, 6-10, 14-17

Form PCT/ISA/210 (continuation of second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
, ᴗT/US2004/040169

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
GB 766728	A		NONE			
DE 765809	C	29-11-1954	NONE			
US 3283509	A	08-11-1966	NONE			
WO 02081883	A	17-10-2002	NONE			
US 2611241	A	23-09-1952	NONE			
US 2004025490	A1	12-02-2004	NONE			
US 5584660	A	17-12-1996	DE	69603361	D1	26-08-1999
			DE	69603361	T2	20-01-2000
			EP	0823958	A1	18-02-1998
			JP	11504407	T	20-04-1999
			WO	9634181	A1	31-10-1996
US 4631092	A	23-12-1986	CA	1244327	A1	08-11-1988
			DE	3569577	D1	24-05-1989
			EP	0181713	A1	21-05-1986
			JP	1036551	B	01-08-1989
			JP	1554641	C	23-04-1990
			JP	61106739	A	24-05-1986